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Novel methods to help develop healthier eating habits for eating and weight disorders: a systematic review and meta-analysis

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Abstract

This paper systematically reviews novel interventions developed and tested in healthy controls that may be able to change the over or under controlled eating behaviours in eating and weight disorders. Electronic databases were searched for interventions targeting habits related to eating behaviours (implementation intentions; food-specific inhibition training and attention bias modification). These were assessed in accordance with the Preferred Reporting Items for Systematic reviews and Meta-Analyses (PRISMA) guidelines. In healthy controls the implementation intention approach produces a small increase in healthy food intake and reduction in unhealthy food intake post-intervention. The size of these effects decreases over time and no change in weight was found. Unhealthy food intake was moderately reduced by food-specific inhibition training and attention bias modification post-intervention. This work may have important implications for the treatment of populations with eating and weight disorders. However, these findings are preliminary as there is a moderate to high level of heterogeneity in implementation intention studies and to date there are few food-specific inhibition training and attention bias modification studies.

Keywords:

Implementation Intentions, Attention Bias Modification, Food-specific Inhibition Training, Eating Disorders, Eating Behaviour, Anorexia Nervosa, Bulimia Nervosa, Binge Eating Disorder

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1. Introduction

The transdiagnostic term eating disorders covers syndromes with eating behaviours ranging from under to over controlled eating (Fairburn et al., 2003). The most common form of psychological treatment across the spectrum of illnesses is Cognitive Behavioural Therapy (CBT) and the main elements used to change eating behaviours are monitoring (eating and compensatory behaviour diaries) and setting goals for food plans, which include regularly spaced meals. However, even in the optimal conditions of a clinical trial these approaches are only moderately effective and 40-60% of patients remain symptomatic at the end of treatment. In order to help explain this resistance of eating disorder symptoms to change, explanatory models have begun to focus on the role of habit formation in the development and maintenance of psychopathology (O'Hara et al., 2015; Steinglass & Walsh, 2006; Treasure et al., 2014; Walsh, 2013).

A staging model of eating disorders (Treasure et al., 2014) has recently highlighted how eating disorder psychopathology may follow a projected trajectory across the lifespan with symptoms becoming more embedded and complex over time. In the severe and enduring stage of illness it is hypothesised that eating disorder habits are deeply entrenched resulting in neuroprogressive changes and decreased

treatment responsiveness. Excessive habit formation is proposed to be a mechanism that maintains the compulsive nature of dietary restriction in Anorexia Nervosa (AN) (Walsh, 2013) and the impulsive/compulsive nature of overeating behaviours in obesity, Binge Eating Disorder (BED) and Bulimia Nervosa (BN) (Berner & Marsh, 2014; Smith & Robbins, 2013). Parallels have been drawn between the role of habit formation in eating and weight disorders and other impulsive/compulsive disorders (Robbins et al., 2012). Based upon this emerging area of research, the purpose of this review will be to examine the effectiveness of novel approaches for developing healthier eating habits that may be valuable in the treatment of eating and weight disorders.

1.1. Excessive habit formation and compulsivity in AN: transdiagnostic comparisons

Gardner (2015) defines habit as, “a process by which a stimulus automatically generates an impulse towards action, based on learned stimulus-response association” (p.280). Walsh (2013) proposed that excessive habit formation might be a maintenance mechanism in AN. This model states that dietary restriction is initially goal-directed with a variety of possible aims such as losing weight or managing emotions etc. Individuals develop fixed dietary patterns and exclude a wide variety of foods from their diet. They may also engage in over-exercising behaviours as a means of weight-loss. During this stage

weight loss may be positively reinforced, with individuals often reporting that they received compliments or concern from their peers and family and an increased sense of self-esteem/ mastery. However, when maintained over time, dietary restriction may develop into a deeply entrenched habit primarily driven by automatic (stimulus-response rather than goal-driven) processes that are initiated by cues that are both internal (e.g., negative affect, physiological effects) and external (e.g., interpersonal difficulties) to the individual. Over time excessive habit formation may underpin the shift from weight-loss being initially rewarding to becoming compulsive in its nature.

Compulsivity involves the repetitive performance of actions that often result in negative consequences. These actions are typically the result of rigid-rules and are performed as a means of avoiding the perceived negative consequences of not carrying out the action (e.g., strict dietary rules may be followed in AN due to a fear of becoming overweight if they are broken) (Dalley et al., 2011; Fineberg et al., 2014; Fontenelle et al., 2011). Robbins et al. (2012) have advocated for a transdiagnostic approach to compulsivity based upon commonalities in cognitive, behavioural and neural processes across disorders and co-morbidities. This approach suggests that research should focus on transdiagnostic constructs to help aid treatment development rather than on traditional diagnostic criteria.

Comparisons have been drawn between compulsivity in AN and other compulsive disorders such as: substance use disorder, obsessive-compulsive disorder (OCD), and obsessive-compulsive personality disorder (Godier & Park, 2014; Park et al., 2014). For example, the persistent nature of weight-loss in AN has been likened to compulsive drug-taking in substance use disorder as these behaviours both continue despite their detriment to health (Godier & Park, 2015). Theories of habit formation are well established within the fields of substance use disorder and OCD, suggesting that the excessive formation of stimulus-response behaviours leads to compulsive drug-taking behaviours in substance use disorder (Everitt & Robbins, 2015; Pierce & Vanderschuren, 2010) and stereotyped/ ritualised behaviours in OCD (Gillan et al., 2014; Gillan & Robbins, 2014). It is possible that excessive habit formation might be a mechanism that underpins compulsivity across disorders (Robbins et al., 2012). Consequently, there is a need for interventions that could help to break the stimulus-response habits that maintain compulsive behaviours.

1.2. How overeating transitions from an action to a compulsion: the role of impulsivity and habit formation

Impulsivity is multifaceted and predisposes individuals to act without forethought to potential negative consequences (Dalley et al., 2011; Fineberg et al., 2014). The construct is considered to comprise of

numerous sub-domains including deficits in inhibiting responses, attention and decision-making (Reynolds et al., 2008). Impulsivity manifests in a range of illnesses such as: substance use disorder (Grant & Chamberlain, 2014), impulse-control disorders (Grant & Potenza, 2006), gambling disorder (Blanco et al., 2009) and Attention-Deficit Hyperactivity Disorder (ADHD) (Lopez et al., 2015). As a result, a transdiagnostic approach to impulsivity has been argued for alongside compulsivity (Robbins et al., 2012). It is thought that both constructs may co-exist within and across a range of disorders and that the balance of the two constructs might contribute to their specific psychopathology (Grant & Kim, 2014; Grant & Potenza, 2006).

The action-to-habit theory of substance use disorder suggests that drug use may initially begin as an impulsive action that becomes compulsive through excessive habit formation (Everitt & Robbins, 2005; Everitt & Robbins, 2015). This action-to-habit theory may also help to explain how compulsive overeating develops (Robbins et al., 2012; Smith & Robbins, 2013). For example, within western societies whereby palatable foods are widely available, impulsivity might predispose individuals towards overeating. Episodes of overeating might become linked with cues (e.g., advertisements/ negative affective states) that trigger food cravings and further overconsumption (e.g., binge-eating). This may lead overeating to transition from being an impulsive action to compulsion. Evidence has been found to support the role of habit formation and impulsivity/ compulsivity in obesity, BED and BN.

1.3. Impulsivity and compulsivity in obesity

It is possible that impulsivity underlies obesity as individuals may find it harder to resist unhealthy palatable foods (Nederkoorn et al. 2006). Nederkoorn et al. (2006) found that treatment-seeking obese children had less inhibitory control and were more sensitive to rewards than age matched healthy controls. Notably, poorer inhibitory control was found to be associated with less successful weight-loss during treatment (Nederkoorn et al., 2006; Nederkoorn et al., 2007). Similar findings of increased impulsivity and deficits in inhibitory control have also been reported in obese adolescents (Batterink et al., 2010) and young adults (Chamberlain et al., 2015; Jasinska et al., 2012).

Excessive habit formation may lead to the maintenance of overeating behaviours. Hortsman et al. (2015) recently found through a selective satiation task that a higher Body Mass Index (BMI) in adult males is linked with lower levels of behavioural sensitivity to changes in the motivational value of food. Habitual responding to food cues could be a mechanism leading to behaviours such as late meal cessation and eating in the absence of hunger (Hortsman et al. 2015). Thus, food cues might prompt obese individuals to overeat paralleling substance use disorder whereby drug related cues can induce compulsive drug-taking (Everitt & Robbins, 2015).

1.4. BED: the impulsive-compulsive nature of binge eating episodes

Binge eating is defined by episodes of overeating objectively large amounts of food accompanied by a subjective sense of loss of control. BED involves recurrent binge eating episodes that are associated with feelings of distress and guilt (American Psychiatric Association, 2013). Obesity and BED are strongly connected with obese BED displaying high levels of impulsivity (Schag et al. 2013a; Schag et al., 2013b) and compulsivity (Davis, 2013). Nazar et al. (2014) reported an association between BED and ADHD in a cross-sectional study of treatment-seeking obese women. Inattention symptoms and impulsivity traits were found to be strong predictors of binge eating severity. Food cues might highly engage the attentional focus of BED patients and decrease awareness on other cognitive processes, thus leaving them vulnerable to impulsive triggers of binge-eating (Nazar et al., 2014; Schag et al., 2013b).

Impulsive binge eating episodes might become compulsive due to excessive habit formation. Voon et al. (2015) used a decision making task to demonstrate that obese individuals with BED show a greater tendency to favour habit-based rather than goal-based learning approaches relative to obese non-BED. Neuroimaging data showed lower orbitofrontal cortex (OFC) and caudate nucleus grey matter volume in obese BED in comparison to obese non-BED. Hence, a bias towards habit-formation and neural deficits might underlie the compulsive nature of obese BED. This is similar to substance use

disorder; with research finding that lower grey matter volume in the OFC is associated with a longer duration of illness and greater levels of compulsivity (Ersche et al. 2011).

1.5. The impulsive-compulsive nature of binge-purge behaviours in BN

BN is characterised by binge eating episodes and compensatory behaviours to prevent weight-gain (purging, laxative abuse, over-exercise and dietary restriction) (American Psychiatric Association, 2013). Pearson et al. (2015) have outlined a risk to maintenance model of BN suggesting that binge eating and purging episodes might begin as emotion driven impulsive actions that can become maintained as maladaptive emotion regulation strategies. For example, binge-eating episodes might initially be experienced as rewarding as they help to distract from the experience of negative emotions. After episodes of binge eating, purging might reduce feelings of guilt and discomfort. Over time, these behaviours develop into a means of avoiding anticipated painful emotions altogether rather than distracting from them. This is thought to parallel substance use disorder whereby drug taking may also be a method of avoiding distressing emotions (Baker et al., 2004). Therefore, binge-purge behaviours in BN might transition from being impulsive to compulsive behaviours that serve an avoidant function. In support of this, Engel et al. (2005) have found that higher levels of self-reported impulsivity and compulsivity are associated with

greater levels of eating disorder psychopathology, depression and drug/alcohol addictions in community and treatment seeking females with BN.

Taken together, findings from across, obesity, BED and BN seem to support the notion that impulsivity and excessive habit formation are mechanisms underlying the compulsive nature of their psychopathology (Robbins et al., 2012).

1.6. Promoting healthier habit formation in dietary change

Based upon the role of excessive habit formation in eating and weight disorders interventions are needed to focus on creating new healthier habits alongside the disruption of the stimulus-response linkage that underpins maladaptive habits (Lally & Gardner, 2011; Wood & Rünger, 2015). Various novel interventions have recently been developed which interrupt this process by planning (e.g., implementation intentions) or acting through more automatic processes such as changing the attentional processes (e.g., attention bias modification training) or impulsive action tendencies (e.g., food-specific inhibition training) which determine eating behaviour (Quinn et al., 2010; Rothman et al., 2009; Wood & Neal, 2007). These approaches have been drawn from other fields such as substance use disorder (e.g., Cox et al., 2014; Wiers et al., 2013), and may be helpful as novel treatment enhancers for eating and weight disorders (Treasure et al., 2015).

1.7. Novel approaches for developing healthier eating habits and breaking maladaptive habits

1.7.1. Implementation intentions

An approach to optimise planning and goal setting for behaviour change is implementation intentions (Gollwitzer, 1999). The aim of this approach is to strengthen deliberate processes of behaviour (van Koningsbruggen et al., 2014) by building counter habits. It involves the creation of action plans that state when, where and which behaviours should be performed in order to achieve a desired goal (Gollwitzer, 1999). For example, ‘if I realise that I am calorie counting, then I will distract myself,’ or ‘if I need to buy a snack from a vending machine, I plan to get a whole-grain fruit bar’. These interventions are part of the motivational phase of behavior change and are based upon the framework of the Theory of Planned Behaviour (TPB) (Ajzen, 1985). They can be used to either help develop a new healthier response to a situation or to increase self-control over maladaptive habits (Lally & Gardner, 2011).

Adriaanse et al. (2011b) performed a systematic review and meta-analysis of the literature relating to implementation intentions finding that they appear to be a helpful approach for increasing healthy food consumption ($d = .51$) and less so for reducing the consumption of

highly palatable foods ($d = .29$). However, this study did not examine the long-term effectiveness of these changes or the impact of this approach on weight change. Furthermore, recently more studies in this area have been conducted meaning that it may be considered necessary to systematically review the effectiveness of this approach further.

1.7.2. Food-specific inhibition training

Food-specific inhibition training is an approach that involves increasing inhibitory control specifically towards highly palatable foods (Veling et al., 2011a). It involves the use of computerised tasks such as the go/no go task and stop-signal task as a means of inhibiting automatic impulses towards highly palatable foods (Houben, 2011; Veling et al., 2011a). Go/ no go training is based upon a choice reaction time paradigm whereby subjects are instructed to respond quickly and accurately to the presentation of a stimulus in the middle of a computer screen. This stimulus is presented alongside either a go or no/go cue such as the letters “P” or “Q” and only appears on screen for a brief period of time. Participants are instructed pre-task to respond to the presentation of a go cue (e.g., by pressing a computer key such as space bar) and to withhold their response when the stimulus is presented alongside a no-go cue. Outcomes recorded for the go/ no go task include reaction times to the stimuli and the accuracy of responses. When participants do not successfully withhold their response for the no-go cue it is indicative of a greater level of impulsivity (Band & van

Boxel, 1999). Through this approach pictures of highly palatable food stimuli can be consistently paired with no-go cues with the goal of increasing self-control towards these items of food.

Regarding the stop-signal paradigm, a similar procedure is followed to go/ no go training with participants receiving instructions to respond rapidly to the onscreen presentation of stimuli whilst withholding their response when a stop-signal appears onscreen (e.g., a border around the target stimuli becoming bold). However, the procedure of stop-signal training differs from go/ no go training in several ways: 1) participants must respond quickly to the presentation of both neutral and target stimuli onscreen; 2) participants are instructed to inhibit their response for only a proportion of the target stimuli; and 3) there is a variable delay between the presentation of the food stimulus onscreen and the presentation of the stop-signal (Verbruggen & Logan, 2008). The stop-signal paradigm can be used as an assessment of the capability to suppress an already initiated motor response with longer reaction times to the stop-signal suggestive of a higher level of impulsivity and poor inhibitory control (Logan et al., 1997). This approach may also be used to increase inhibitory control towards highly palatable foods and may be of value in the treatment of disorders of overeating such as obesity, BED and BN (Juarascio et al., 2015).

1.7.3. Attention bias modification

Research has suggested that biases in attention might underlie either under or over eating. For instance, patients with AN have been found to have biases in attention away from highly palatable foods (Veenstra & de Jong, 2012). In populations that overeat attentional biases towards highly palatable foods have been reported (Kemps et al. 2014a; Nijs, et al. 2010; Nijs & Franken, 2012; Werthmann et al., 2015). The goal of attention bias modification is to remediate these cognitive biases in attention and to decrease the saliency of the environmental cues that may trigger eating habits.

The attention bias modification approach is computerised and is based upon a modified version of the dot-probe task and can be used to train early orientation styles in attention either towards or away from food or emotional stimuli (MacLeod et al., 1986). To do this, two stimuli appear onscreen either side of a fixation point; one food related, the other neutral. Following this a probe appears (e.g., the letter “E” or “I”) which subjects must respond to quickly by pressing a computer key. To train attention towards food the probe consistently appears in the position vacated by the food stimuli or the neutral stimuli to train avoidance. Attention bias modification training may have potential as a widely disseminable treatment enhancer for eating disorders (Renwick et al., 2013) in either helping to develop healthier food intake or diminishing unhealthy food consumption.

The aim of the present systematic review and meta-analysis of the literature is to examine and compare the effectiveness of methods

that have been found to change eating behaviours (i.e., implementation intentions, food-specific inhibition training and attention bias modification training). This is with the overall aim of translating possible new methods into clinical practice.

2. Method

2.1. Literature search

The electronic databases Embase, Medline, PsycINFO using Ovid and Science Citation Index Expanded (1900-present) and Scopus were searched for relevant articles written in English in peer reviewed journals during available years of publication to October 2014 following the PRISMA guidelines (Moher et al., 2009). The keywords used as search terms can be found in table 1.

-----TABLE 1-----

2.2. Inclusion/ exclusion criteria

To be included in the systematic review and meta-analysis, studies were required to meet the following criteria: 1) measured the effectiveness of at least one session of a training intervention (i.e., implementation intention/action planning, food-specific inhibition training or attention bias modification); 2) eating behaviour and/or

weight change as the primary outcome; and 3) random allocation of participants to the experimental or control condition.

2.3. Study Selection

One author (K.B.) performed the literature searches for the different training approaches and screened studies based on the content of their abstracts. Full text articles were assessed by two independent reviewers after which final screening and assessment for eligibility was agreed by two authors (K.B. and R.T.) Moreover, both authors (K.B. and R.T.) manually searched for studies by screening the reference lists of retrieved manuscripts and inspecting bibliographies from relevant labs in the field of these training approaches. If available, relevant articles at the submission stage or in preparation by the authors of these labs were screened as well. The process of inclusion and exclusion of studies is shown in the PRISMA diagrams of study selection for all three training approaches separately (Figures 1 to 3). A third reviewer was included in this process if there was uncertainty.

2.4. Data collection

In order to prepare data for meta-analyses means (M), standard deviations (SD) and sample sizes (n) for both intervention and control (or comparison) groups were extracted from the articles. In studies where the Standard Error (SE) was reported, the SD was calculated from the SE using the following formula $\bar{x} = s/\sqrt{n}$. When data could not be retrieved from the articles, corresponding authors were contacted by email. Articles were excluded from meta-analysis when authors did not provide the particular data following two email requests.

2.5. Statistical analyses

Analyses were performed using Stata 11.0 (Stata Corporation, College Station, TX, USA) using the metan command (Bradburn et al., 1998), metanbias and metatrim (Steichen, 1998). The mean difference between intervention and control or comparison group for each training approach is measured by the Cohen's d effect size, the difference between two raw means divided by the pooled standard deviation. Cohen's effect sizes were interpreted as negligible ($\geq -.15$ and <0.15), small (≥ 0.15 and <0.40), medium (≥ 0.40 and <0.75), large (≥ 0.75 and <1.10), very large (≥ 1.10 and <1.45) and huge (≥ 1.45). Regarding the evaluation of the effect of different training approaches multiple meta-analyses were performed and presented in Forest Plots. In regard to training approaches that aim to increase healthy eating behaviours a positive Cohens'd effect size favours the training approach; whilst a

negative Cohen's d effect size favours the effect of training over control conditions in decreasing unhealthy food intake or reducing food intake. Random effects multivariate meta-analyses were performed to account for possible heterogeneity in the data and for both within and between study variance (Chen et al., 2012).

In order to assess the consistency of the results found and for any evidence of heterogeneity amongst the data the I^2 percentage was calculated for each finding (Higgins et al., 2003). I^2 scores range from 0-100% and describe the total variation across the studies included in the meta-analysis and indicate whether the findings may be due to sampling error or heterogeneity. Values of 25, 50 and 75% are interpreted as suggesting low, moderate and high levels of heterogeneity respectively. Publication bias was examined through the Egger's test (Egger et al., 1997), Begg's adjusted rank test (Begg & Mazumdar, 1994) and the trim and fill method (Duval & Tweedie, 2000). If these tests suggested that there was evidence for publication bias, funnel plots were completed to assess for publication bias in greater detail.

-----FIGURES 1-3-----

-----TABLES 2 to 8-----

3. Results

3.1 The effect of implementation intentions

3.1.1. Overview of included studies

In total 48 studies were included examining the effect of implementation intentions on food intake and weight change. Studies were divided into different groups examining the effect of implementation intentions on; 1) increasing healthy food intake (see Table 2) and; 2) reducing unhealthy food intake (see Table 3). In the present meta-analysis a third group was identified examining the effect of implementation intentions on; 3) weight change (see Table 4). Results are discussed in these groups separately.

3.1.2. Implementation intentions aimed at increasing healthy food intake

Five studies (de Nooijer et al., 2006; De Vries et al., 2008; Luszczynska et al., 2007c; Stadler et al., 2010 & Verplanken & Faes, 1999) were excluded from the analysis because standard deviations and/or means were not reported. One more study was excluded from meta-analysis since the effect size was more than three times higher above the average effect size and therefore considered as an outlier (Zhang & Cooke, 2012). Consequently, in total twenty-three studies were included in the forest plot (please refer to Figure 4).

-----FIGURE 4-----

Participants in the implementation intention group increased their healthy food intake with a small effect size of 0.26 (95%CI: 0.16 to 0.37) compared to the control groups. There was evidence for publication bias (Begg's test $p=.012$; Egger's test $p=.011$). The trim and fill method estimated that nine studies were missing from the analysis resulting in an adjusted negligible effect size of 0.12 (95%CI: 0.01 to 0.24) after correcting for publication bias. For example, the funnel plots (Figure 5) suggested that small studies with null effects are missing. Furthermore, because heterogeneity was found to be high ($I^2=69.9\%$), a meta-regression was performed in which the variables, intervention type, time after intervention and outcome measures were entered. This simple model did not explain the heterogeneity.

-----FIGURE 5-----

Nine studies had outcome measures recorded after a follow up period (please refer to Figure 6). People in the implementation intention group were slightly more successful in increasing healthy food intake with a small effect size of 0.23 (95%CI: 0.08 to 0.38) relative to the control groups. We found no evidence for publication according to Begg's test ($p=0.451$), however Egger's test did ($p=0.006$). The trim and fill

method estimated that six studies were missing from the analysis; the adjusted effect size is negligible 0.05 (95%CI: -0.1 to 0.19) after correcting for publication bias. The funnel plots (Figure 7) suggest that there is a lack of small sample size studies contradicting the effect of implementation intentions and a lack of larger sample sizes examining advocating the effect of implementation intentions on increasing healthy eating behaviour at follow up.

-----FIGURE 6-----

-----FIGURE 7-----

Heterogeneity was found to be moderate ($I^2=58.2\%$). A further inspection of the subgroups revealed that the implementation intention only subgroup showed no heterogeneity ($I^2=0.0\%$) while in the implementation plus group heterogeneity was found to be $I^2=66.9\%$. Therefore, a meta-regression was performed in which intervention type was entered. However, intervention type was not found to significantly explain the heterogeneity of the studies ($p=.343$).

3.1.3. Implementation intentions aimed at reducing unhealthy food intake

Three studies were excluded from the analysis because standard deviations and/or means of the data were not reported (De Vries et al., 2008) or the dependent variable was formulated as the success rate of reducing unhealthy food intake (Adriaanse et al., 2010; Study 2). The study of Zhang and Cooke (2012) was excluded for the same reason as for the effect of implementation intention on increasing healthy food intake.

Seventeen studies were included in the forest plot (please refer to Figure 8). Participants in the implementation intention group reduced their unhealthy food intake with a small effect size of -0.31 (95%CI: -0.44 to -0.19). We found no evidence for publication bias (Begg's test $p=0.544$; Egger's test $p=0.970$). Heterogeneity was found to be moderate for the total sample ($I^2=47.3\%$). Further inspection of the subgroups suggests that this heterogeneity was mainly due to the moderate to high heterogeneity in the implementation intention plus group ($I^2=68.2\%$) compared to the small heterogeneity in the implementation intention only group ($I^2=11.7\%$). Therefore, a meta-regression was performed in which type of implementation intention intervention was entered as variable. Type of intervention did not significantly explain the variance although a trend was indicated ($p=0.083$).

-----FIGURE 8-----

Four studies had outcomes measured at follow up and were included in the forest plot shown in figure 9. People in the implementation intention group were slightly more successful in reducing unhealthy food intake with a small effect size of -0.16 (95%CI: -0.29 to -0.02) relative to the control groups. We found no evidence for publication bias (Begg's test $p=0.548$; Egger's test $p=0.463$) or heterogeneity ($I^2=35.3\%$). The data in the forest plot were ordered by time at follow up, and visually this suggests the effect of implementation intention on reducing unhealthy food intake declines with time.

-----FIGURE 9-----

3.1.4. Implementation intentions aimed at changing weight

One study was excluded from the meta-analysis (Luszczynska & Haynes, 2009) because data including standard deviations and/or means were not reported pre- and post-intervention. Six studies were included in the forest plot (please refer to Figure 10). The overall effect size of implementation intentions for changing weight (effect size = 0.04; 95%CI: -0.08 to 0.17) or BMI, 0.09 (95%CI: -0.06 to 0.23) was negligible. In regards to the effectiveness of implementation intentions in changing weight (kg), the effect size was also found to be small (-0.07; 95%CI: -0.35 to 0.20). No evidence for heterogeneity was found

($p=0.15$, $I^2=36.1$). The Begg's ($p=0.37$) and Egger's tests ($p=0.051$) were performed to examine for publication bias. Due to the Egger's test being close to statistical significance a funnel plot was created (Figure 11). This highlighted that there may be a lack of small sized studies that do not support the impact of implementation intentions on weight.

-----FIGURE 10-----

-----FIGURE 11-----

3.1. The effect of food-specific inhibition training on reducing food intake

In total fifteen studies were identified. Eight studies were excluded from the meta-analysis for a variety of reasons: the primary outcome was a computerised measure rather than actual food intake (Van Koningsbruggen et al., 2013, Study two; Veling et al., 2013, Study 1 and Study 2); it was the only study considering weight change (Veling, 2014); the control group also received food-specific inhibition training towards highly palatable foods (Houben & Jansen, 2014) or the inhibition training was not food-specific (Guerrieri et al., 2009, Study 1 and Study 2; Guerrieri et al., 2012; Lawrence et al., 2015, Study 3). Six studies were included in the meta-analysis forest plot (please refer to Figure 12).

-----FIGURE 12-----

Stop-signal training produced a small to medium reduction in food intake (effect size of -0.39 (95%CI: -0.67 to -0.11). Go/ no go training produced a medium effect size in reducing food intake (-0.58, 95% CI: -0.97, -0.19). Overall, food-specific inhibition training had an effect size of -0.46 (95%CI: -0.67, -0.25) in reducing food intake. A non-significant small amount of heterogeneity was found for the go/ no go approach ($I^2=33.6\%$). There was evidence of publication bias (Begg's test $p=0.024$; Egger's test $p=0.012$). Funnel plots were performed (Figure 13) which highlighted that there may be a small amount of publication bias; relating to a lack of small sized studies that do not support the effectiveness of food-specific inhibition training. Only one study (Veling et al., 2014) examined weight change during four weeks of internet delivered food-specific inhibition training and found no effect ($d=0.03$). Overall, based on Figure 13, there also appears to be a lack of large sized studies examining the effects of food-specific inhibition training.

-----FIGURE 13-----

3.3. The effect of attention bias modification

3.3.1. Overview of included studies

In total six studies were found: 1) (n = 4) reducing unhealthy food intake (Table 6); 2) (n = 2) increasing healthy food intake (Table 7); and 3) (n = 2) increasing unhealthy food intake (Table 8). A meta-analysis was only completed for the effect of attention bias modification in reducing unhealthy food intake only due to the limited number of studies found for the other two groups. The limited amount of evidence found so far has indicated that attention bias modification might be useful in increasing healthy food intake. Kakoschke et al. (2014) found a moderate effect size of 0.36 for increasing healthy food intake. In regards to increasing unhealthy food intake, a mean effect size of 0.18 has been found from the two studies conducted to date (Hardman et al., 2013; Werthmann et al., 2014).

3.3.2. Attention bias modification aimed at reducing unhealthy food intake

Four studies were included in the meta-analysis (please refer to Figure 14). Overall, attention bias modification had an effect size of -0.51(95%CI: -0.81, -0.22) in reducing unhealthy food intake. A significant small amount of heterogeneity was found overall ($I^2=25.9\%$). There was no evidence of publication bias (Begg's test $p=.734$; Egger's test $p = .138$).

-----FIGURE 14-----

4. Discussion

4.1. Summary of the results

The aim of this review was to examine the effectiveness of approaches that may be beneficial for developing healthier eating habits in eating and weight disorders. A primary finding from this review is that no studies using these approaches in clinical populations with AN, BN and BED were found in the literature. This was surprising considering the recent formulations of these illnesses based around habit-theory and impulsivity and/ or compulsivity (Robbins et al., 2012; Treasure et al., 2014; Walsh, 2013). A limited number of studies using the implementation intention approach with overweight/ obese individuals were found. The implementation intention approach was found to have small effect sizes post-intervention in increasing healthy food intake and reducing unhealthy food intake with negligible effects at follow-up respectively. More promisingly, medium effect sizes were found for the impact of food-specific inhibition training and attention bias modification in reducing unhealthy food intake. Caution may be taken in making any definite conclusions regarding the effectiveness/ clinical application of these approaches though due to the moderate to high level of heterogeneity found in the data for the implementation intention approach and the limited number of studies over the follow-up period examining food-specific inhibition training and attention bias modification.

A previous meta-analysis that focused on the implementation intention approach (Adriaanse et al., 2011b), found a larger effect size for increasing healthy food intake ($d = 0.59$) compared to the present study. A possible explanation for the smaller effect size found in this review may be due to the more stringent inclusion criteria followed in this review. For instance, (Adriaanse et al., 2011b) stated that their finding might have been inflated due to the poor quality of control conditions included in the review. Furthermore, the present study excluded correlational studies meaning that the inclusion of studies that involved the random allocation of participants to an experimental or control condition may have led to a more valid effect size being found. This was done in order to specifically address the question of whether these approaches might be beneficial as interventions for developing healthier eating habits in clinical populations. The result from this review that the implementation intention approach also has a small effect size in reducing unhealthy food intake is similar to the small effect size ($d = 0.29$) reported by Adriaanse et al. (2011b). This review extended this finding by also examining follow up data that suggested that over a one-year period the small effect of implementation intentions in reducing unhealthy food intake diminishes. To date this is the first review to systematically examine the effectiveness of food-specific inhibition and attention bias modification training.

4.2. Implications of the findings

The finding from this review that the implementation intention approach has a small effect size in increasing or reducing food intake

suggests that when used alone this approach may not be successful in helping individuals to develop healthier eating habits (Verplanken & Wood, 2006). It is conceivable that if implementation intentions are to be used in the treatment of AN they may be of most benefit when used in conjunction with other approaches such as the self-monitoring techniques used in CBT. This may allow for the identification of maladaptive habits which implementation intentions may then be targeted at (Lally & Gardner, 2011). It may also be hypothesised that implementation intentions may most beneficial at the earlier stages of treatment than in the severe and enduring stage of AN whereby eating habits are more compulsive and resistant to change (Steinglass & Walsh, 2006; Treasure et al., 2014; Walsh, 2013). At this earlier stage of illness, implementation intentions could be most likely to help prevent the development of fixed eating habits. However, this hypothesis needs testing.

Implementation intentions might also be most effective when combined with other interventions in obesity, BED and BN. Research has found that the effectiveness of implementation intentions' is moderated by the trait of impulsivity (Churchill & Jessop, 2011). This trait has been found to be elevated in individuals with obesity, BED and BN (Claes et al., 2005; Mobbs et al., 2010) meaning that it may be beneficial to combine implementation intentions with other interventions that increase participants' levels of self-control such as food-specific inhibition training. A limited amount of research in non-

clinical populations has not found additive effects of combining implementation intention and food-specific inhibition training approaches such as the go/no-go task (van Koningsbruggen et al., 2014; Veling et al., 2014). However, these studies have focused on undergraduate student samples and do not assess the long-term impact of the training on eating behaviour. Further research may be beneficial in clinical populations (i.e., obesity, BED and BN) to further elucidate whether combining implementation intention with self-control interventions is beneficial. This might employ other types of behaviour specific food-specific inhibition training than the go/no-go task such as the stop-signal task.

In the present review the effect of implementation intentions in reducing unhealthy food intake was found to diminish over time. One reason why behaviour change interventions may fail longitudinally is that although behaviours change can occur in the short-term, environmental and contextual cues may trigger unwanted habits to recur (Wood & Rünger, 2015). Walker et al. (2014) suggests that when developing a new habit there is an initial “window of opportunity for change” that is then followed by a “window of vulnerability to relapse” (p.12) as the unhealthy habit may not be entirely extinguished for at least four weeks. One method to increase the effectiveness of implementation intentions over time could be to use reminders of implementation intention plans (e.g., via text-message post-study; Prestwich et al., 2009) or to offer booster sessions of implementation

intention training post-intervention. Another helpful approach to help prevent old habits from recurring might be to combine the implementation intention approach with attention-bias modification to help reduce the saliency of environmental cues that may trigger old unwanted habits such as unhealthy eating. This could possibly help maintain the development of new healthy habits.

The approaches of food-specific inhibition training and attention bias modification were found to have medium effects sizes in reducing food intake in healthy populations. These training paradigms could be useful for increasing self-control over highly palatable foods in obesity, BED and BN. Strengths of these approaches are that they may be widely disseminated and cost-effective with the potential for them to be used alongside existing psychological interventions. For instance, in substance use disorder attention bias modification approaches may be optimised by combining them with motivational support interventions (Boffo et al., 2015; Wiers et al., 2013). This approach might be beneficial for treatment resistant patients with eating disorders that have difficulties engaging with traditional ‘talking therapies’ or who have low levels of motivation to change (Renwick et al., 2013).

4.3. Methodological considerations and limitations of the review

It should be noted that there are limitations to the literature in this review. Studies examining the effectiveness of food-specific inhibition

training and attention bias modification training have been conducted in highly controlled laboratory settings. Consequently, the long-term effectiveness of these approaches on eating behaviour in real-life settings appears unclear. Although the results appear promising for the effectiveness of the food-specific inhibition training and attention bias modification approach on reducing food intake, caution may also be taken in interpreting these findings due to the scarcity of studies using these approaches and the different control conditions used by studies. Due to the limited amount of literature a meta-analysis could not be performed to examine the effectiveness of attention bias modification training to increase healthy or unhealthy food intake.

This review focused on the primary effects of the different training approaches. Research has indicated that individual differences such as levels of dietary restraint might impact upon the effectiveness of food-specific inhibition training (Lawrence et al., 2015). In regards to attention bias modification training, another factor that could moderate the impact of the training is participant's accuracy of responses on the task (as measured through the use of eye-tracking technology; Werthmann et al., 2014). Consequently, future endeavours could seek to examine the impact of moderating variables on the different training approaches. This would help to indicate whom the training approaches might be most beneficial for.

Another consideration that should be taken into account is the relatively heterogeneous and diverse groups/populations surveyed across the studies included in this review. For example, the meta-analysis into the effectiveness of attention bias modification in reducing unhealthy food intake included both child (Boutelle et al., 2014) and adult samples (e.g., Hardman et al., 2013). Although studies are appearing to suggest that attentional biases towards food stimuli are evident in obese children, the strength of the available evidence at present may be considered greater for adults (Boutelle et al., 2014). Accordingly, further research into attention bias modification in both children and adult samples could help to clarify whether the findings of this present review are replicated in more homogenous samples. Before this occurs, caution may be taken in interpreting the promising preliminary findings of this review.

4.4. Directions for future research in clinical populations

Given the finding that there is currently a lack of studies in clinical populations further research is needed that examines the effectiveness of the different training approaches in eating and weight disorders. This proof of concept work may help to experimentally assess whether these preliminary findings translate to clinical populations whereby eating disorder habits are more severe and long-standing.

In substance use disorder it has been suggested that it may be beneficial to tailor training approaches such as attention bias modification and

inhibition training to the individual in order to gain more potent effects (Wiers et al., 2013). In eating disorders these approaches could also be tailored so that they are disorder-specific. For instance, clinically meaningful distinctions have been reported between binge eating episodes and overeating episodes without a sense of loss of control or emotional distress. Therefore, it could be beneficial to adapt approaches such as food-specific inhibition for individuals with BED or BN so that they are helpful when experiencing negative affect. The stimuli used in the training approaches could also be tailored towards an individual's specific 'trigger' foods for binge eating in these illnesses (Juarascio et al., 2015).

This present review has primarily focused on developing healthier eating habits through the use of cognitive/ behavioural approaches. Habit based interventions could also be of benefit in the treatment of other compulsive behaviours in eating and weight disorders such as over-exercising, body checking and purging. For instance, implementation intentions could be adapted to help reduce purging behaviours (e.g., If I feel overwhelmed with the urge to purge after dinner, then I will call up my family for support). Attention bias modification training away from body-related cues may also be beneficial to reduce body checking (Smeets et al., 2011). Novel pharmacological and neuromodulation approaches have also recently emerged as novel treatment approaches for eating disorders and may be helpful to target impulsive/ compulsive systems in people with

severe and enduring illnesses (McClelland et al., 2013; Oudijn et al., 2013; Treasure et al., 2015).

4.5. Conclusion

To summate, there is preliminary evidence that implementation intentions, food-specific inhibition training and attention bias modification may change habitual eating behaviours in predominantly healthy populations. Before any firm conclusions can be drawn about the effectiveness of food-specific inhibition training and attention bias modification, further research is needed due to the current limited number of studies. Future studies may benefit from more rigorously designed control groups and longer-term follow-ups. This might lead to the development of interventions that could be of value in clinical populations.

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Figure captions

Figure 1. Flow Diagram on the search and selection of studies on implementation intentions.

Figure 2. Flow Diagram on the search and selection of studies on food-specific inhibition training.

Figure 3. Flow Diagram on the search and selection of studies on attention bias modification.

Figure 4. A forest plot for the effectiveness of the implementation intention approach for increasing healthy eating. Abbreviations: II = Implementation Intentions; MC = Mental Contrasting; SA = Self-affirmations; TPB = Theory of Planned Behaviour; SE = Self-efficacy; TPBQ = Theory of Planned Behaviour Questionnaire; MI = Mental Imagery; C = Coping Planning.

Figure 5. A funnel plot to assess publication bias for studies examining the effect of implementation intentions on increasing healthy food intake.

Figure 6. A forest plot for the effect of the implementation intention approach for increasing healthy eating at follow-up. Abbreviations: II = Implementation Intentions; SA = Self-Affirmations; TPB = Theory of Planned Behaviour; SE = Self-Efficacy; TPBQ = Theory of Planned Behaviour Questionnaire; C = Coping Planning.

Figure 7. A funnel plot to assess publication bias at follow-up for the implementation intention approach for increasing healthy eating.

Figure 8. A forest plot for the implementation intention approach for decreasing unhealthy eating post-intervention. Abbreviations: II = Implementation Intentions; MC = Mental Contrasting; TPB = Theory of Planned Behaviour; SE = Self-efficacy; AI = Activity Imagery.

Figure 9. A forest plot for the implementation intention approach for reducing unhealthy eating at follow-up. Abbreviations: II = Implementation Intentions; TPB = Theory of Planned Behaviour.

Figure 10. A forest plot to show the effectiveness of the implementation intention approach for changing weight. Abbreviations: II = Implementation Intentions; SA = Self-Affirmations; TPB = Theory of Planned Behaviour.

Figure 11. A funnel plot to examine for publication bias for implementation intentions to change weight post intervention.

Figure 12. Forest plot to show the effectiveness of food-specific inhibition training to reduce food intake. Abbreviations: SST = Stop Signal Training; BTT = Bogus Taste Test; DRT = Double Response Training.

Figure 13. Funnel plot for the meta-analysis of food-specific inhibition training on reducing unhealthy food.

Figure 14. A forest plot to show the effectiveness of attention bias modification in reducing unhealthy food intake.

Tables

Table 1. Search terms used for the different training approaches

Construct (type of training)	Search Terms (* indicates truncation)
1. Implementation Intentions or action planning	(Implementation intention OR action planning) AND (food OR diet* OR eat*OR weight)
2. Food-specific inhibition training	(food OR diet* OR eat* OR weight) AND (inhibition OR impuls* OR self-control) AND (stop signal OR no-go)
3. Attention bias modification	Attention* bias AND (modification OR *training) AND (food OR diet* OR eat*OR weight)

Table 2. A summary of the included papers for Implementation intentions on increasing healthy eating behaviours

	Training Condition	Control condition	Session(s)	Time between plan and outcome	Behavioural outcome	Participants (at baseline)	Effect size (Cohen's d)
Adriaanse et al. (2009) Study 1	Implementation intentions with a motivational cue	Control	1	Directly after manipulation (for 7 consecutive days)	Food diary for 7 consecutive days; mean number of healthy snacks a day	108 female students	0.84
Adriaanse et al. (2009) Study 2	Implementation Intention with a personal motivational cue	Control	1	Directly after manipulation (for 7 consecutive days)	Food diary for 7 consecutive days; mean number of healthy snacks a day	72 female students	0.65
Adriaanse et al. (2010) Study 1	Implementation intention with mental contrasting	Control	1	Directly after manipulation (for 7 consecutive days)	Food diary for 7 consecutive days; portions of fruit in the past week	51 female students	0.13
Armitage (2007)	Implementation intentions	Control	1	2 weeks	Fruit intake over the last two weeks (sum)	120 students	0.61
					Number of days in the last two weeks where participants ate an extra piece of fruit		0.47
Armitage (2014)	Self-incentivising implementation intention	Control	1	1 month	Fruit intake using the fruit section of Bogers Frequency Measure	238 adolescents consuming fewer than 3	-0.08

						portions of fruits a day	
Chapman and Armitage (2010)	Implementation Intention plus an implementation intention at 3 months	Control	2	2 x 3 months	Single open-ended item: Fruit and vegetable intake per day over the last week	650 undergraduate students	3 months: 0.24 6 months: 0.37
					FFQ: average fruit and vegetable consumption over the past year		3 months: 0.10 6 months: 0.09
Chapman and Armitage (2012)	Implementation Intentions for fruit and vegetables separately	Control	1	2 months	Single open-ended item: Average portions of fruit a day over the past week	580 students	0.16
					Single open-ended item: Average portion of vegetables a day over the past week		0.25
Chapman et al. (2009)	Implementation intention	Control	1	1 week	Single open-ended item: Average fruit and vegetable intake a day over the past week	557 undergraduate students	0.13
*de Nooijer et al. (2006)	Implementation Intentions	Control	1	1 week	FFQ; Mean daily fruit consumption in grams	535 participants	NR

*de Vries et al. (2008)	Tailored health information letter plus Implementation Intentions	Tailored health information letter only	3x1 (letters; only action planning in last letter)	9 months	FFQ: Vegetable and fruit consumption; number of days in the past week (frequency) and average amount a day	2827 participants recruited through Dutch National Telephone Survey	-0.17 (fruit) -0.05 (vegetable) (derived from the paper)
Epton et al. (2014)	Online intervention based on Implementation intentions, a self-affirmation task and theory of planned behaviour messages	Control	Provided in app (participants could sign up for email reminders; read the interventions numerous times)	1 month 6 months* *! After starting University (still enrolled in intervention)	Fruit and vegetable intake (portions per day) was measured with items based on the Health Survey for England (HSE)	1445 students (recruited 2 weeks prior to start of University year)	0.13 -0.02
Gratton et al. (2007)	Implementation Intentions	Control (implementation intention on homework)	1	1 week	7 day food diary Mean amount of fruit and vegetable portions in a week	198 children (secondary school)	0.71
Guillaumie et al. (2012)	Implementation intention plus self-efficacy	Control	4 x 2 hour group meetings	At the end of the 1 month intervention 3 months	Self-report 6-item questionnaire on fruit and vegetable intake over the past week; average per day	163 participants	0.61 0.59
Guillaumie et al. (2013)	Implementation intention plus self-efficacy	Control	4 x 2 hour group meetings	6 months 12 months	Self-report 6-item questionnaire on fruit and vegetable intake	291 participants	0.39 0.28

					over the past week; average per day		
Harris et al. (2014)	Self-affirmed implementation intentions	Control (non affirmed; non implementation intentions)	1	1 week	Three measures assessing fruit and vegetable consumption (single open-ended item consumption on a typical day; Cambridge FFQ and consumption in a typical week on 7 points Likert Scale; results were standardized)	332 participants (students and staff at University)	0.79
				3 months			0.69
Jackson et al. (2005)	Implementation Intention plus a Theory of Planned Behaviour Questionnaire	Control	1	7 days	Food diary of the previous 24 h; daily fruit and vegetable consumption (portions)	120 cardiac patients	-0.11
				28 days			0.21
				90 days			0.06
Karimi- Shahanjarini et al. (2013)	Implementation intentions plus Theory of Planned Behaviour	Control	3 x 90 minutes	10 days	FFQ (Iranian version) assessing healthy snacks (26 options) over the past week	739 adolescent girls	-0.33
				3 months			-0.01
Kellar and Abraham (2005)	Implementation intentions plus self-efficacy	Control	1	1 week	Single open-ended item: The number of days over the past week in which participants ate the	218 undergraduate psychology students	0.34

					required daily intake of fruit and vegetables		
Knäuper et al. (2011a)	Implementation intentions plus mental imagery	Control	1	1 week`	Single open-ended item: Number of fruit portions a day (average over the past week)	247 first year undergraduate students	0.30
Kothe et al. (2011)	Implementation intentions plus self-efficacy (called perceived behavioural control (PBC) in this paper)	Control	1	4 weeks	Single open-ended item: Number of days eaten breakfast over the past week	378 undergraduate students	-0.19
Kreausukon et al. (2012)	Intervention using self- efficacy tasks , Implementation intentions and coping planning ⁷	Control (nutrition education only)	Several sessions lasting one weekend	1 week	Average serving of vegetables and fruit a day over the past week	114 undergraduate students	0.53
				6 weeks			0.49
Lange et al. (2013)	Implementation Intentions plus Self efficacy, action control and coping planning	Control (received nutrition quiz)	1 (45 minutes)	1 week	Average fruit intake a day over the past week	791 participants	0.21

Luszczynska and Haynes (2009)	Implementation intentions	Control	3 (directly after measurement, after 6 and 9 weeks)	4 months after the first implementation intention session	Two –item questionnaire on 5 point Likert Scale; Mean number of fruit and vegetable intake a day	182 students (46% BMI > 25)	0.26
*Luszczynska et al. (2007c)	Implementation Intentions plus Self-efficacy	Control	2 x 1 (received email for both self-efficacy and action plans based on scores at T0)	6 months	Single item question on 7-Points Likert Scale; fruit and vegetable consumption over the past two weeks; average a day scored	285 participants (adults) 26% were overweight/ obese	NR
Reuter et al. (2008) Study 2	Implementation Intentions	Control	1	4 weeks	Average portion of fruit and vegetables a day over a period of four weeks	115 participants (only n=19 in control group)	0.52
*Stadler et al. (2010)	Implementation Intentions with mental contrasting ²	Control	1	1 week 1 month 2 months 4 months 24 months	Food diary assessing fruit and vegetable intake for 7 consecutive days; Daily servings of fruits and vegetables were summed up per week.	255 women	NR
Tam et al. (2010)	Promotion focused	Control	1	Directly after manipulation for 2 consecutive days	A self-reported online food diary of healthy	559 undergraduate students	0.13

	implementation intention				snacks over a 2-day period (one each day)		
*Verplanken and Faes (1999)	Implementation intentions	Control	1	Directly after intervention (for five consecutive days)	Food diary for five consecutive days rated by blinded dieticians on a 2 point Likert Scale (bad, reasonable, good) on 6 aspects of food intake; resulting in a Mean healthiness rating	102 undergraduate students	0.47 (derived from paper)
Wiedemann et al. (2012)	Implementation intentions (formulating 1, 2, 3, 4 or 5 plans)	Control	1	1 week	Single open-ended item: fruit and vegetable intake eaten on a typical day over the past week	478 participants	0.48 (5 plans)
Zandstra et al. (2010)	Implementation intentions	Control	1	(2 weeks) (3 weeks)	4-week diary assessing the amount of meal replacement food usages; average amount of MR per week	57 overweight consumers using website on meal replacement foods	0.31 0.04
*Zhang and Cooke (2012) (a)	Implementation Intentions plus Self Efficacy (through the use of protection	Control	2 x 1 (first session focused on	4 weeks (2 weeks after II)	Adapted form of the FFQ; measuring fruit and vegetable intake	84 students	1.42 (4 weeks; 2 weeks after action plans)

motivation
messages)

motivation;
second on II)

* Excluded from the meta-analysis. Abbreviations: FFQ = Food Frequency Questionnaire. In this table a positive Cohen's d is indicative of an increase in healthy eating behaviour and supports the effectiveness of the intervention.

Table 3. A summary of the papers included for the effect of Implementation intentions on reducing unhealthy eating behaviours

	Training Condition	Control condition	Session(s)	Time between plan and outcome	Behavioural outcome	Participants	Effect size
Achtziger et al. (2008) Study 1	Implementation intentions	Control	1	1 week	Two open-ended items; Change in the number of specified snack foods consumed in the past week	92 undergraduate students	-0.41
Adriaanse et al. (2009) Study 1	Implementation intentions with a motivational cue	Control	1	Directly after manipulation (for 7 consecutive days)	Food diary for 7 consecutive days; mean number of calories of consumed unhealthy snacks a day	108 female students	-0.09
Adriaanse et al. (2009) Study 2	Implementation Intention with a personal motivational cue	Control	1	Directly after manipulation (for 7 consecutive days)	Food diary for 7 consecutive days; mean number of unhealthy in kcal snacks a day	72 female students	-0.62
Adriaanse et al. (2010) Study 1	Implementation intention with mental contrasting	Control (made a list of top 10 healthy snacks)	1	Directly after manipulation (for 7 consecutive days)	Food diary for 7 consecutive days; sum of kcal for unhealthy snacks in past week	51 female students	-0.82
*Adriaanse et al. (2010) Study 2	Implementation Intention with mental contrasting	Mental contrasting only	1	1 week	Success of reducing unhealthy snack habit rated on 7 Point Likert Scale (3 items)	59 female participants	0.75

Adriaanse et al. (2011a) Study 3	Replacement implementation intentions	Intention only (I will not eat chocolate)	1	Directly after manipulations (for 7 consecutive days)	Snack diary for 7 consecutive days; Assessing the frequency of unhealthy snacking over the past week and Kcal consumed in the past week (for unhealthy snacks only)	130 female students	-0.23
Armitage (2004)	Implementation intention	Control	1	1 month	Fat intake (in grams) a day (calculated using a self-report food frequency instrument; report food over the past month)	264 participants	-0.34
*de Vries et al. (2008)	Tailored health information letter plus Implementation intentions	Tailored health information letter only	3x1 (letters; only action planning in last letter)	9 months	Fat intake in grams (calculated from self- reported intake of 19 possible products or product groups)	2827 participants recruited through Dutch National Telephone Survey	0.06 (derived from paper)
Karimi- Shahanjari et al. (2013)	Implementation intentions plus Theory of Planned Behaviour	Control	3 x 90 minutes	10 days 3 months	FFQ (Iranian version) assessing the number of unhealthy snacks (22 options) over the past week	739 adolescent girls	-0.52 -0.32
Knäuper et al. (2011b)	Implementation intention plus activity imagery	Goal intention control condition (form a goal to	1	1 to 4 days after manipulation	Log sheets for craving for 4 consecutive days; number of servings of	119 participants (students and	-0.07

		reduce craving without concrete strategy)			the food/drink participants consumed	staff University)	
Kroese et al. (2011) Study 2	Implementation intention	Control	1	1 week	Single open-ended item: Average chocolate consumption a day over the past week	56 female participants	-0.46
Luszczynska et al. (2007a)	Implementation intentions	Control	1	6 months	Daily saturated fat intake; measured using Meat Snack section of Rapid Food Screener	130 cardiac patients	-0.56
Prestwich et al. (2008)	Reasoning implementation intentions plus self-efficacy (protection motivation message)	Control	1	1 month	Saturated fat intake (as a percentage of total self-reported food intake) over the past month; measured using Meat Snack section of Rapid Food Screener	210 participants	-0.49
Prestwich et al. (2014)	Collaborative implementation intentions	Control	1	1 month 3 months 6 months	Fat intake (as a percentage of total self-reported food intake) over the past month; measured using Meat Snack section of Rapid Food Screener	393participant s	0.09 -0.02 0.05

Scholz et al. (2013)	Implementation intentions	Control	1 group session (supervised) and 8 consecutive sessions by mail	4 months	Fat consumption in grams assessed by 24 hour recall by structured interviews	373 individuals with BMI>25	0.11
				6 months			-0.09
				12 months* *After baseline assessment			0.01
Sullivan and Rothman (2008)	Implementation intentions	Control	1	1 week	Caloric intake (kcal) Fat intake (grams); Measured by 1 week recall using the self-report Eating habits Measure	145 students	Caloric intake
				2 weeks			-0.41
							-0.33
							Fat intake -0.26 (1 week) -0.35 (2 weeks)
Van Koningsbruggen et al. (2011) Study 2	Think of dieting implementation intention	No-treatment control condition	1	2 weeks	Mean rating of frequency and amount of 5 critical food items averaged (using a 7 points Likert Scale)	236 participants	-0.43
Van Koningsbruggen et al. (2014) Study 1	No-go task plus diet primed implementation intentions	Control (implementation intentions on non-food items only)	1 (for no go task; 12 (6 trials each)	1 day	Mean standardised amount of sweets (weight and size) obtained from a food serving behaviour measure with a sweet-shop like environment	89 participants	-0.58

*Van Koningsbruggen et al. (2014) Study 2	No-go task plus diet primed implementation intentions	Control (implementation intentions on non-food items only)	1 (for no go task; 12 (6 trials each)	The same day (after fulfilling a word completion task)	Average amount of selected portion size in computerised snack dispenser (0-500)	88 students in social sciences	-0.53
*Zhang and Cooke (2012)	Implementation intentions plus self-efficacy (through use of protection motivation messages)	Control	2 x 1 (first session focused on motivational; second on volitional)	4 weeks (motivation; 2 weeks after volitional)	Fat intake percentage of total food intake measured by adapted form of the FFQ	84 students	-1.26 (4 weeks; 2 weeks after action plans)

* Excluded from meta-analysis. Abbreviations: FFQ= Food Frequency Questionnaire. In this table a negative Cohen's d is indicative of a decrease in unhealthy eating behaviours and supports the effectiveness of the intervention.

Table 4. A summary of the papers included for the effect of Implementation intentions on changing weight

	Training Condition	Control condition	Session(s)	Time between plan and outcome	Behavioural outcome	Participants	Effect size (Cohen's d)
Epton et al. (2014)	Online intervention based on implementation intentions, a self-affirmation task and theory of planned behaviour messages	Control	Provided in app (participants could sign up for email reminders; read the interventions numerous times)	1 month	BMI	1445 students (recruited 2 weeks prior to start of University year)	0.17
6 months*				0.06			
*! After starting University (still enrolled in intervention)							
*Luszczynska and Haynes (2009)	Implementation intentions and self-efficacy	Control	3 (directly after measurement, after 6 and 9 weeks)	4 months first implementation intention	BMI (self-report)	182 students (46% BMI > 25)	-0.29
Luszczynska et al. (2007b)	Implementation intentions	Control	8 (2 months; 1 supervised)	2 month after baseline assessment	BMI (computed in weight loss program)	50 overweight and obese women	-0.31
					Body weight (idem)		-0.14
Prestwich et al. (2014)	Collaborative implementation intentions	Control	1	6 months	Body weight (kg); self-report	427 participants	-0.16

Veling et al. (2014)	Implementation intentions plus food no-go training	Control (no implementation intentions and no go training without food pictures)	4	4 to 5 weeks from baseline assessment (after 4 weeks of training)	Weight loss in kg (session 1 – session 2)	113 participants	-0.13
Zandstra et al. (2010)	Implementation intentions	Control	1	4 weeks	BMI; self-reported	57 overweight consumers using a website on meal replacement foods	-0.24

*Excluded from meta-analysis; Abbreviations: BMI= Body Mass Index; kg= kilograms. Hereby, a negative Cohen's d is indicative of a decrease in weight and supports the effectiveness of the intervention.

Table 5. A summary of the included papers for the effect of food-specific inhibition training on reducing food intake

	Training Condition	Control condition	Session(s); Trials in each session	Behavioural outcome	Participants	Effect size (Cohen's d)
*Guerrieri et al. (2009) Study one	An inhibition priming task	An impulsivity priming task	1; 1	Amount of food intake on a bogus taste test	46 female undergraduates	NR
*Guerrieri et al. (2009) Study two	Stop-signal task: training inhibition by instructing participants to focus on stopping	Stop-signal task: training impulsivity by instructing participants to focus on speed	1; 96	Amount of food intake on a bogus taste test	46 female undergraduates	NR
*Guerrieri et al. (2012)	Stop-signal task: the no. of stop trials rose by 5% in each block	Reading two neutral stories	1; 600	Amount of food intake on a bogus taste test	61 female undergraduates	NR
Houben (2011)	High calorie food paired with a stop signal	High calorie food paired with go signal on half the trials	1; 288	Calories consumed on a bogus taste test	29 female undergraduates	-0.34
Houben and Jansen (2011)	Go- no go task: Chocolate paired with a no-go	Chocolate paired with go signal on half the trials	1; 320	Amount of chocolate consumed	63 female undergraduates	-0.86

Lawrence et al. (2015) Study one	Stop-signal task: snacks paired with a stop signal	Double response training: snacks paired with a stop signal	1; 480	Amount of crisp consumption	54 students/ staff members	-0.56
Lawrence et al. (2015) Study two	Stop-signal task: snacks paired with a stop signal	Double response training	1; 512	Amount of crisps or chocolate consumed during the bogus taste test	136 students/ staff members	-0.32
*Lawrence et al. (2015) Study three	Stop-training – one non-food category always linked to stop	Double response training	1; 512	Amount of crisps or chocolate consumed during the bogus taste test	146 students/ staff members	0.01
Van Koningsbruggen et al. (2014) Study one	Go/ no go task: sweets paired with no-go signal	Sweets not paired with no-go signals	1; 72	Mean standardised amount of sweets (weight and size) obtained from a food serving behaviour measure with a sweet-shop like environment	89 students	-0.77
*Van Koningsbruggen et al. (2014) Study two	Go/ no go task: sweets paired with no-go signal	Sweets not paired with no-go signals	1; 72	The number of snacks requested on a computerised snack dispenser task	88 students	-0.74

Veling et al. (2011a) Study two	Go/ no go task: sweets were paired with no-go signal	Sweets not paired with no-go signals	1; 72	Lower levels of sweet consumption in a take home candy bag task	46 undergraduate students	-0.26
*Veling et al. (2013b) Study one	Stop-signal task: snacks paired with no -go signal	Go signals were paired with snacks	1; 96	Number of choices of unhealthy foods on a computerised task	79 young adults	-0.53
*Veling et al. (2013b) Study two	Stop-signal task: Snacks paired with no – go signal	Go signals were paired with snacks	1; 96	Number of choices of unhealthy foods on a computerised task (Extra condition is frequency of past behaviour scores)	44 young adults	-0.71
*Veling et al. (2014)	Stop-signal task: snacks paired with no - go signal	Neutral pictures linked with no - go signal	4 (1 per week over 4 weeks); 200	Weight loss in kilogram's between the start and end of study	113 participants	0.03

*Excluded from the meta-analysis. For this approach a negative Cohen's d is indicative of a reduction in unhealthy food intake/ weight and supports the effectiveness of the intervention.

Table 6. A summary of the papers included for the effect of attention bias modification training on reducing unhealthy food intake
For this approach a negative Cohen's d suggests a reduction in unhealthy food intake and supports the effectiveness of the intervention.

	Training Condition	Control condition	Session(s); No. of trials	Behavioural outcome	Participants	Effect size
Boutelle et al. (2014)	Trained attention 100% of the time from food words to neutral words	Attention was trained 50% to neutral and 50% to food stimuli	1; 288	Amount of calories consumed in a test meal	29 overweight obese children	-0.27
Hardman et al. (2013)	Training attention away from cake stimuli	Attention was trained 50% to neutral and 50% to food stimuli	1; 768	Amount of the target food (i.e., cake) and non- target food (i.e., crisps) – measured in kcal	60 undergraduate students	-0.04
Kemps et al. (2014b) Study one	Avoid chocolate	Training attention towards chocolate	1; 140	Amount of chocolate consumed in a taste test	110 female undergraduate students	-0.67
Kemps et al. (2014b) Study two	Avoid chocolate	Training attend towards chocolate	1; 140	Amount of chocolate consumed in a taste test	88 female undergraduates	-0.71

Table 7. A summary of the papers found examining the effect of attention bias modification training on increasing healthy food intake

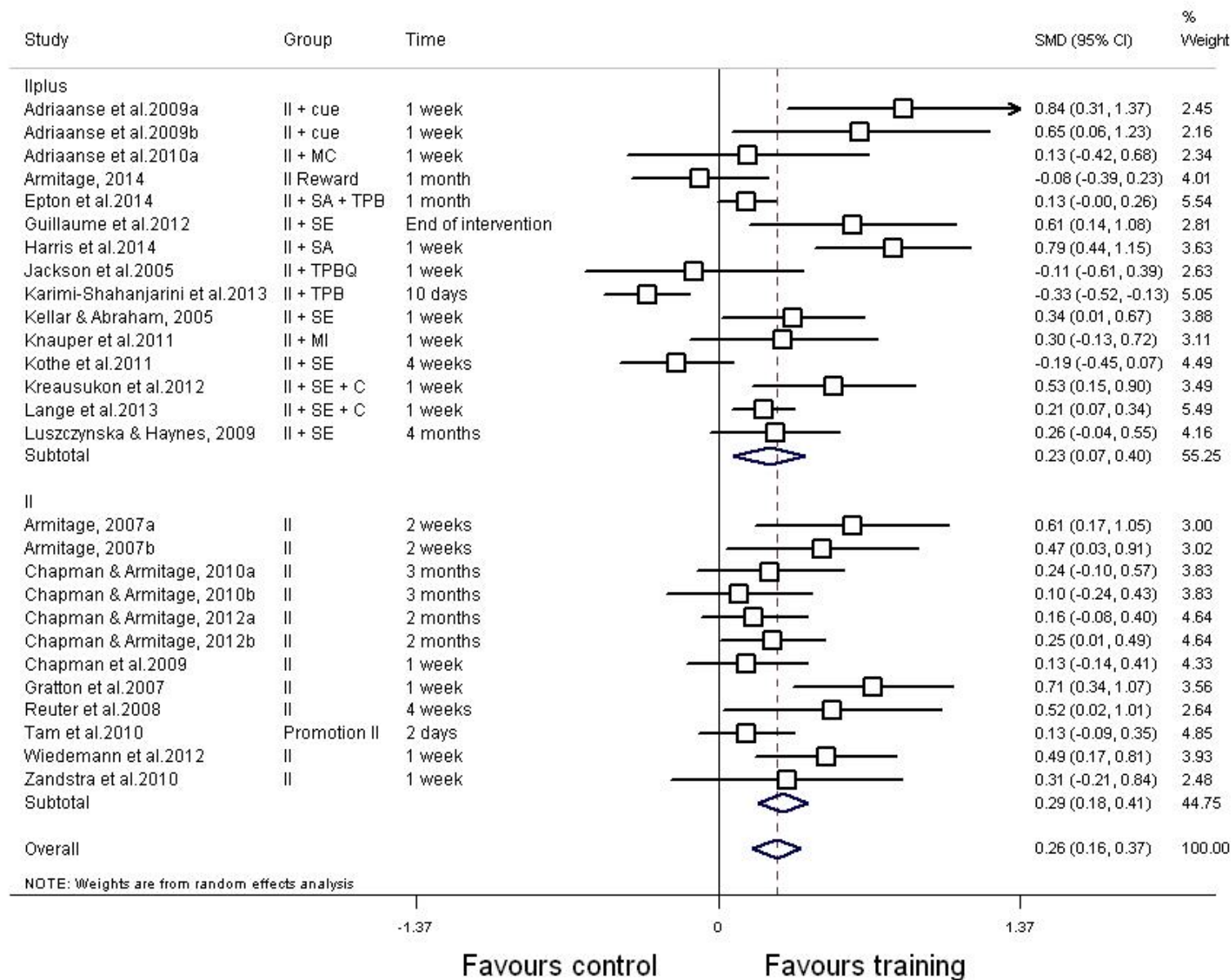
	Training Condition	Control condition	Session(s)	Behavioural outcome	Participants	Effect size (Cohen's d)
*Kakoschke et al. (2014)	Training attention towards healthy food stimuli	Training attention towards unhealthy food stimuli	1; 512	Amount of food consumed on a bogus taste test	146 female undergraduate students	0.36
*Smith & Reiger (2009)	Attend to low calorie food	Neutral	1; 240	Food selection task (as a measure of dietary restriction)	98 female undergraduates	NR

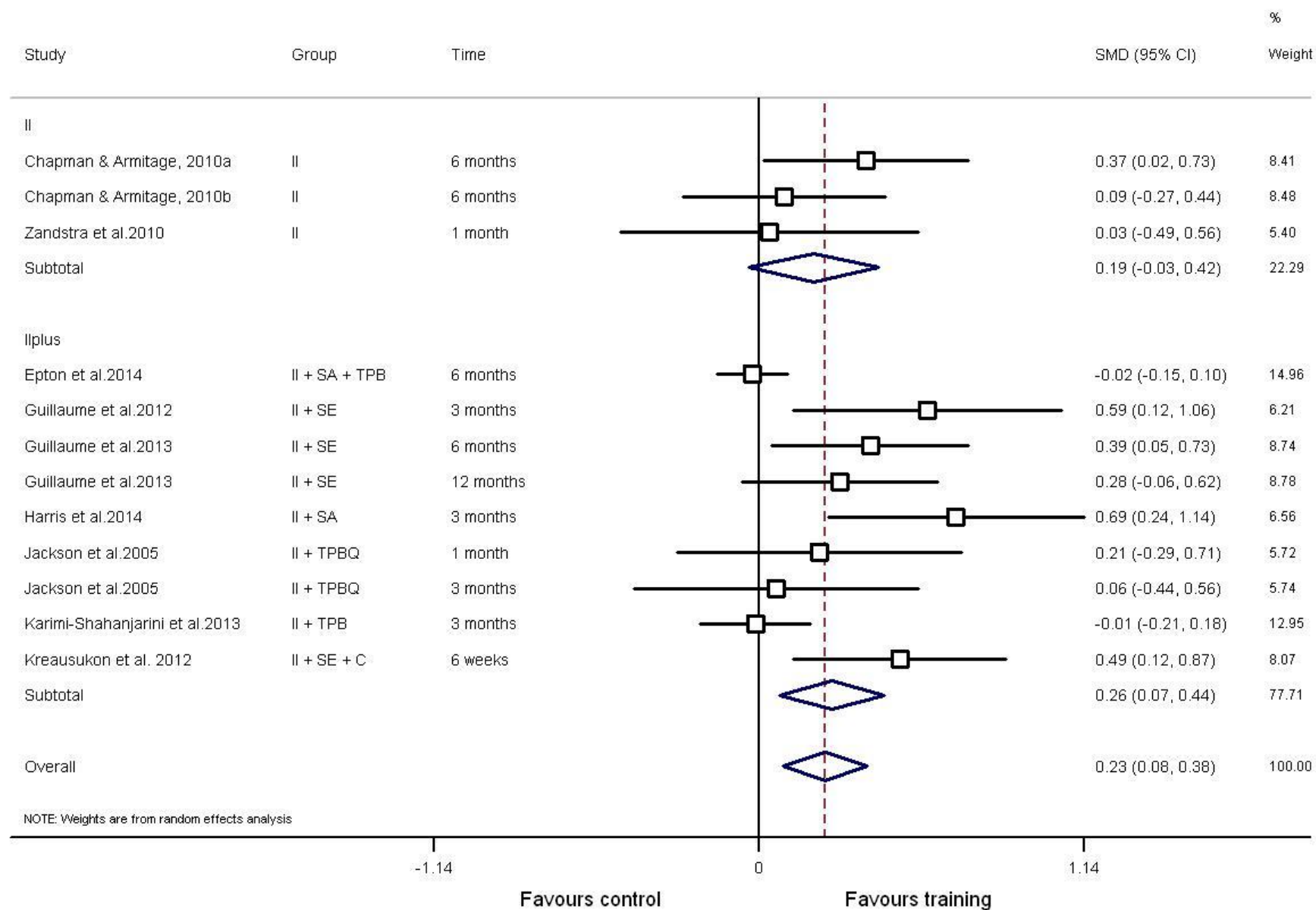
*Excluded from the meta-analysis. For this approach a positive Cohen's d suggests an increase in healthy food intake and supports the effectiveness of the intervention.

Table 8. A summary of the papers found examining the effect of attention bias modification training on increasing unhealthy food intake

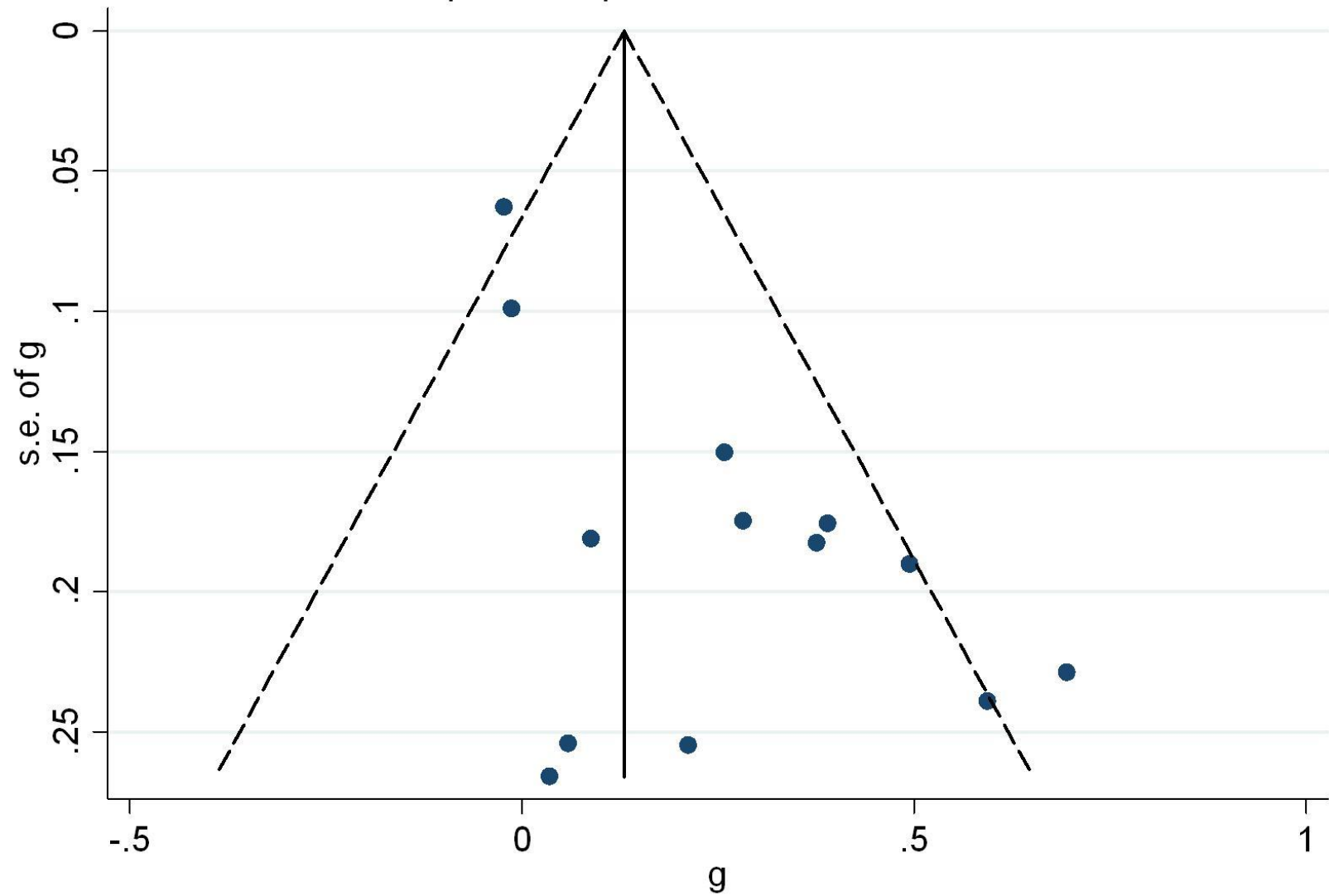
	Training Condition	Control condition	Session(s)	Behavioural outcome	Participants	Effect size (Cohen's d)
*Hardman et al. (2013)	Training attention towards cake stimuli	Attention was trained 50% to neutral and 50% to food stimuli	1; 768	Amount of the target food (i.e., cake) and non-target food (i.e., crisps) – measured in kcal	60 undergraduate students	0.34
*Werthmann et al. (2014)	Attend to chocolate and away from neutral stimuli (i.e., shoes) ^a	Attend to neutral stimuli (i.e., shoes) and away from chocolate	1; 320	Amount of chocolate consumed in a taste test	56 female undergraduate students	0.02

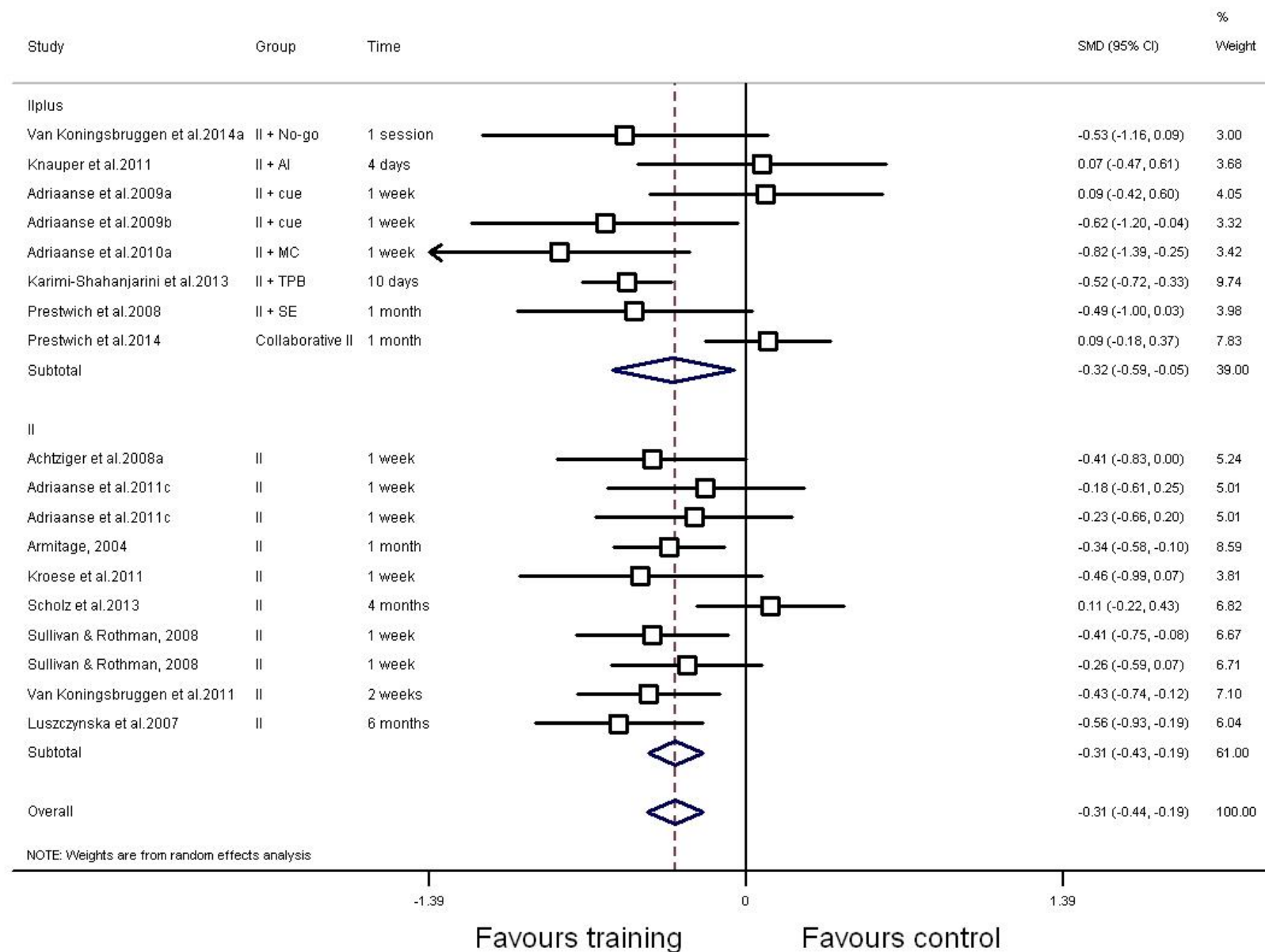
*Excluded from the meta-analysis. For this approach a positive Cohen's d is indicative of an increase in unhealthy food intake and supports the effectiveness of the intervention. ^aWerthmann et al. (2014) used a novel version of an antisaccade task to modify attention. In this task participants were instructed to direct their eye movements either towards or away from an onscreen target stimuli.

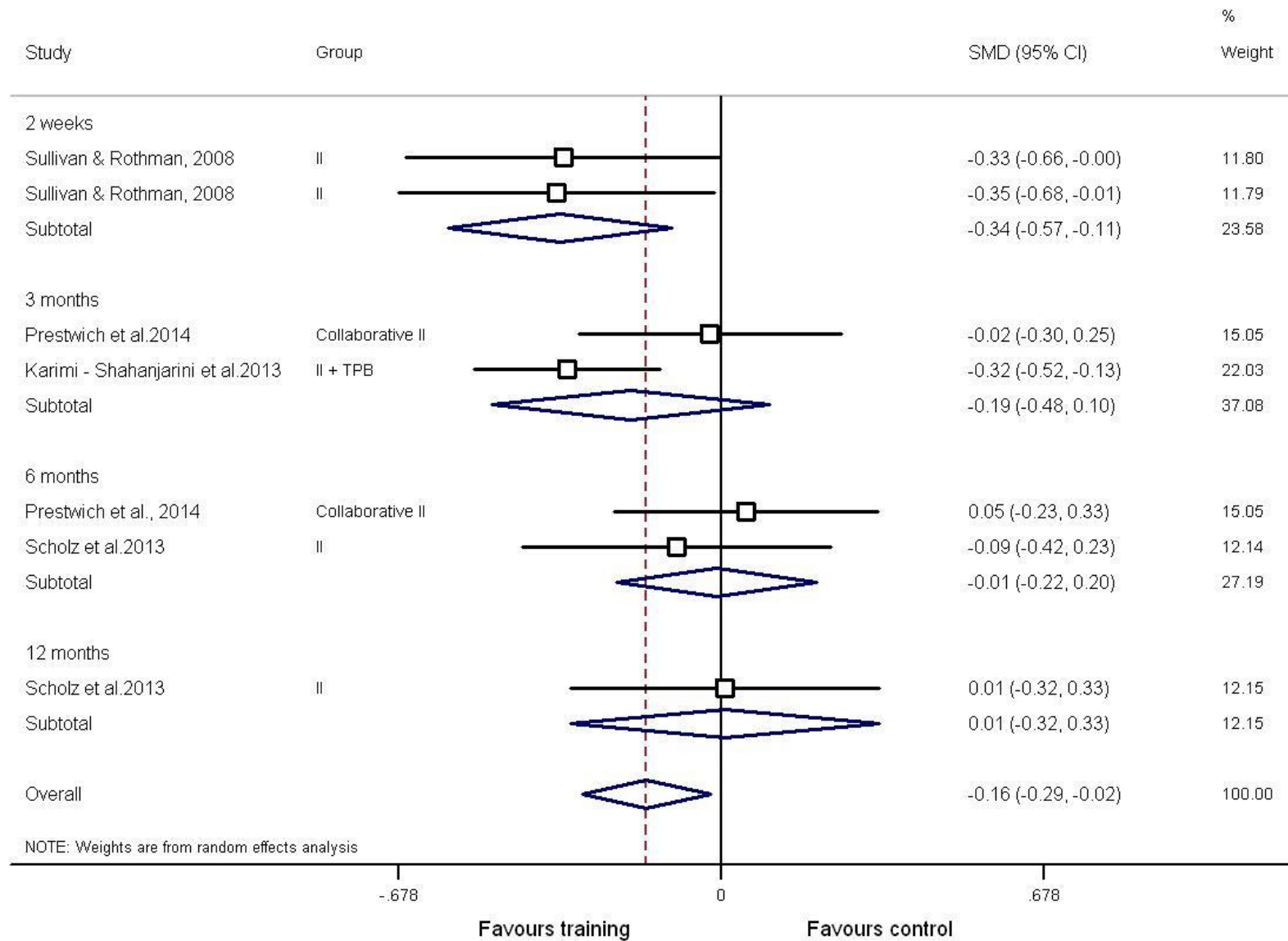


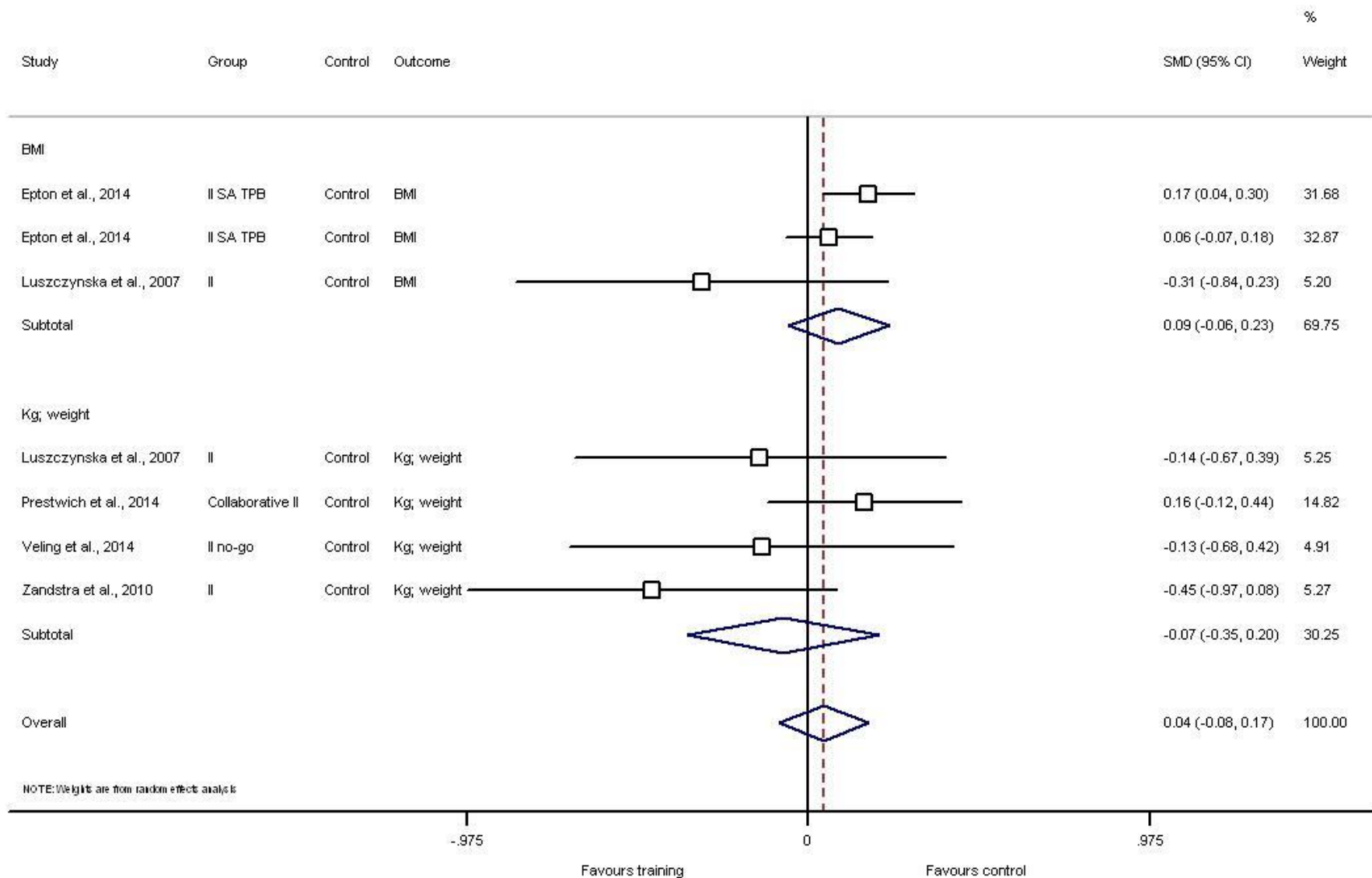


Funnel plot with pseudo 95% confidence limits









Funnel plot with pseudo 95% confidence limits

